European Cells and Materials Vol. 11. Suppl. 3, 2006 (page 19) ISSN 1473-2262

BioDynamic Test Instrument for the Characterization of Tissues and Biomaterials

S. Williams, D. Burke, W. Conrads, T. Nickel, and L. Mejia

Bose Corporation, ElectroForce Systems Group, Eden Prairie, Minnesota, USA.

OBJECTIVE: The objective of this work was to employ the novel design of the BioDynamic testing platform to evaluate the mechanical properties of hydrogels and other composite biomaterials. The testing platform allows for continuous test and stimulation in a fully integrated and instrumented configuration by providing material characterization (viscoelastic properties, strength, creep and stress relaxation) within a physiological environment (nutrient flow, pressure loading, pH, dissolved oxygen, and temperature).

METHODS: An advanced BioDynamic testing platform has been designed that can be used to evaluate the mechanical properties of tissue-engineered constructs for both cardiovascular and musculoskeletal applications. The BioDynamic instrument was used to test a variety of specimens to demonstrate its versatility and advanced features. The dynamic mechanical properties of polyvinyl alcohol hydrogels (Cambridge Polymer Group, Boston, MA) were evaluated with our unique computer-controlled moving magnet linear motor that provides load, displacement, strain or pressure profiles. The hydrogel samples were 3-4 mm in diameter and 3-4 mm in height, and testing was performed in compression with a 5 mm displacement transducer and a 250 gram force transducer. Vascular graft distension with increasing pressure was also evaluated in a BioDynamic instrument using a laser micrometer. The graft material used (Gel-Del Technologies, Inc., St. Paul, MN) is composed of proteins and polymers fabricated to mimic the viscoelastic properties of native blood vessels.

RESULTS / DISCUSSION: The ability to perform very low force applications is illustrated in Figure 1. The peak-to-peak loading on the hydrogel was approximately 2 mN with a corresponding peak-to-peak displacement of 28 μm. A distinct linear region was not observed with a displacement ramp as the specimen made a very gradual change in stiffness as a function of % strain. Figure 2 shows the dynamic mechanical analysis software analysis as a 0.001 N compressive contact force was applied to the specimen. Upon completion of data acquisition, the software calculated the modulus and tan delta for the specimen, which appeared to exhibit resonance between 20 and 100 Hz. Figure 3 shows two cycles of a sinusoidal pressure waveform from 0 to 25 mmHg followed by a cycle of pressure increase to 250 mmHg. The diameter response followed the pressure changes very closely throughout the test. After each cycle, OD did not return to its initial value within the test's time frame, indicating potential creep behavior. A cycle of pressure increase from 0 to 295 mmHg is also shown. The specimen is again exhibiting creep by not returning to its initial diameter over the time frame studied.

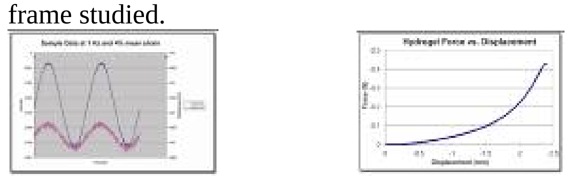

Figure 1: Dynamic material properties of a soft polyvinyl alcohol hydrogel. (Left) low force application, (right) displacement ramp from contact to 430 mN at a rate of 0.02 mm/s.

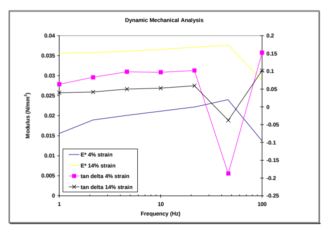

Figure 2: Hydrogel modulus and tan delta at various strain and frequency levels.

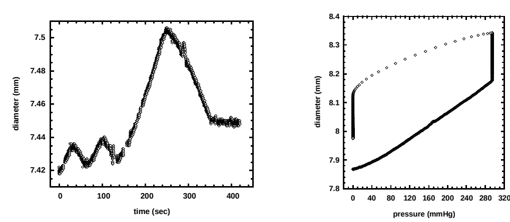

Figure 3: Vascular graft distension versus time in response to pressure changes and diameter change with pressure. (Left) pressure was increased to 25 mmHg for two cycles and to 295 mmHg during the third cycle, (right) linear pressure ramp from 0 to 295 mmHg.

CONCLUSIONS: Preliminary results with hydrogel disks for orthopaedic applications and vascular grafts show that the BioDynamic test instrument is a powerful tool for the integration of biochemical and mechanical stimulation and properties characterization in one system.